The Optical Gravitational Lensing Experiment. The New Catalog of Eclipsing Binary Stars in the Small Magellanic Cloud.*

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ABSTRACT

We present new version of the OGLE-II catalog of eclipsing binary stars detected in the Small Magellanic Cloud, based on Difference Image Analysis catalog of variable stars in the Magellanic Clouds containing data collected from 1997 to 2000.

We found 1351 eclipsing binary stars in the central 2.4 square degree area of the SMC. 455 stars are newly discovered objects, not found in the previous release of the catalog. The eclipsing objects were selected with the automatic search algorithm based on the artificial neural network. The full catalog is accessible from the OGLE INTERNET archive.

Keywords: binaries: eclipsing – Magellanic Clouds – Catalogs

1. Introduction

Precise determination of distances to nearby galaxies is still one of the main goals of modern astrophysics. Eclipsing binary stars were used for this purpose for almost hundred years and in the last decade we witnessed their great "come-back" for two main reasons. First, very large telescopes with mirror diameter more than 6 meters can provide accurate spectroscopy of such faint stars as eclipsing binaries in nearby galaxies. Secondly, long time-base photometry and precise light curves of eclipsing binaries, mostly in Magellanic Clouds and Galactic bulge, are supplied as a by product of microlensing searches, *e.g.*, MACHO

*Based on observations obtained with the 1.3 m Warsaw telescope at the Las Campanas Observatory of the Carnegie Institution of Washington.

(Alcock *et al.* 1997) and OGLE (Udalski *et al.* 1997a, Udalski *et al.* 1998, Wyrzykowski *et al.* 2003).

To date several attempts of distance determination with eclipsing binary method were presented (*e.g.,* Fitzpatrick *et al.* 2003, Fitzpatrick *et al.* 2002, Ribas *et al.* 2002), mostly to the LMC because this value is crucial for the distance scale. The extragalactic distance scale is tied to the LMC distance.

In last few years, the distance to the Small Magellanic Cloud was also determined with eclipsing binary method by several authors: Wyithe and Wilson (2001), Wyithe and Wilson (2002), Harries, Hilditch and Howarth (2003). Their papers were based on the photometry obtained by the OGLE collaboration (Udalski *et al.* 1998), which contained data from the first 1.5 year of observations of the second phase of the OGLE survey (Udalski, Kubiak and Szymański 1997b). However, OGLE-II continued collecting data until the end of 2000. A much larger and almost complete subset of the OGLE-II images was reanalyzed with the image subtraction technique – Difference Image Analysis (Żebruń, Soszyński and Woźniak 2001a). Variable stars detected in that study were presented in the catalog of variable stars in the Magellanic Clouds (Żebruń *et al.* 2001b).

The main aim of this paper is to provide a catalog of eclipsing binary stars in the SMC based on the DIA photometry. The catalog contains 1351 stars, from which only 896 were cross-identified in previous version of the catalog indicating that 455 stars are newly discovered eclipsing binary stars.

The search algorithm and classification method were identical with those used in the catalog of eclipsing binary stars in the LMC (Wyrzykowski *et al.* 2003). We used artificial neural network for recognition of the variability type and divided discovered eclipsing binaries into three classical types: EA (Algol type), EB (β Lyr type) and EW (W UMa type). The sample is reasonably complete at the level of the DIA catalog of variable stars in the SMC although the completeness of the latter drops rapidly for fainter objects. The sample allows statistical analysis of eclipsing binaries in the SMC and should provide a good material for testing theory of evolution of binary systems as well as for studying the evolution of the SMC, star formation or other projects.

2. Observational Data

All photometric data presented in the catalog of eclipsing stars were collected with the 1.3-m Warsaw telescope at the Las Campanas Observatory, Chile, which is operated by the Carnegie Institution of Washington, during the second phase of the OGLE experiment. The telescope was equipped with the "first generation" camera with the SITe 2048×2048 CCD detector working in driftscan mode. The pixel size was 24μm giving the scale of 0.417 arcsec/pixel.

Observations of the SMC were performed in the "slow" reading mode of the CCD detector with the gain $3.8e^-$/ADU and readout noise of about 5.4 e^-. Details of the instrumentation setup can be found in Udalski, Kubiak and Szymański (1997b).

Regular observations of the SMC fields started on June 26, 1997 and covered about 2.4 square degrees of central parts of the SMC. Reductions of the photometric data collected up to the end of May 2000 were performed with the Difference Image Analysis (DIA) package (Woźniak 2000, Żebruń, Soszyński and Woźniak 2001a) and variable stars candidates were published in the catalog of variable stars in the Magellanic Clouds (Żebruń *et al.* 2001b).

T a b l e 1

Equatorial coordinates of the SMC fields

Field	RA (J2000)	DEC (J2000)
SMC_SC1	$0^{h}37^{m}51^{s}$	$-73^{\circ}29'40''$
SMC_SC2	$0^{h}40^{m}53^{s}$	$-73^{\circ}17'30''$
SMC_SC3	$0^{h}43^{m}58^{s}$	$-73^{\circ}12'30''$
SMC_SC4	$0^{h}46^{m}59^{s}$	$-73^{\circ}07'30''$
SMC_SC5	$0^{h}50^{m}01^{s}$	$-73^{\circ}08'45''$
SMC_SC6	$0^{h}53^{m}01^{s}$	$-72^{\circ}58'40''$
SMC_SC7	$0^{h}56^{m}00^{s}$	$-72^{\circ}53'35''$
SMC_SC8	$0^{h}58^{m}58^{s}$	$-72^{\circ}39'30''$
SMC_SC9	$1^{h}01^{m}55^{s}$	$-72^{\circ}32'35''$
SMC_SC10	$1^{h}04^{m}51^{s}$	$-72^{\circ}24'45''$
SMC_SC11	$1^{h}07^{m}45^{s}$	$-72^{\circ}39'30''$

The DIA photometry is based on the *I*-band observations. The catalog of variable stars contains about 15 000 stars in 11 fields of the SMC (Table 1). Each star has at least 300 good photometric measurements. The magnitudes of stars were transformed to the standard system (Udalski *et al.* 2000). The errors of the measurements are about 0.005 mag for the brightest stars ($I<16$ mag) and grow to 0.08 mag at 19 mag and to 0.3 mag at 20.5 mag.

3. Search and Classification of Eclipsing Binary Stars

In order to identify eclipsing binaries we applied here the same algorithm as used in the LMC search Wyrzykowski *et al.* (2003). The main ideas employed are summarized below.

Automated recognition of the variability type is based on artificial neural network algorithm. Among all 15 000 variable stars in the SMC we selected only periodic ones, using the AoV algorithm (Schwarzenberg-Czerny 1989). Next, phased light curves of those stars were transformed to "images", which were the network input.

Because our data come from the same source as in Wyrzykowski *et al.* (2003), *i.e.*, the DIA catalog of variable stars (Żebruń *et al.* 2001b) we did not have to repeat network learning process and used the network with neural weights set

previously for the LMC search. That network was adopted to recognize the basic variability types, as eclipsing, sinusoidal and "saw shaped".

All light curves, which were classified by the network as eclipsing ones, were inspected visually. Then the detected periods were tuned up to smooth the eclipse shape which is very sensitive to period inaccuracies. During visual inspection we divided eclipsing binary stars into three classical types: EA (Algol type), EB (β Lyr type) and EW (W UMa type), according to the Fourth Edition of "General Catalog of Variable Stars" (GCVS, Kholopov *et al.* 1999). For several stars multiple classification (*e.g.*, EB/EW) was chosen, because of difficulties with distinguishing between those two classes. In the case of several stars their variability, classification or period are uncertain. Such objects are marked with additional remark as "uncertain".

Very uncertain objects were excluded at this stage. We also excluded almost 100 objects, which were probably ellipsoidal variables. They were automatically classified as eclipsing binary stars, because the shape of their light curves revealed somewhat different depths of minima. However in the case of some stars we were still unable to clearly distinguish between eclipsing and ellipsoidal variables. Therefore, they are additionally marked with "ELL".

In the case of some objects additional variability of one or both components was superimposed on the clear eclipsing variability. These light variations could be caused by *e.g.*, spots on binary stars, high proper motion of the system (long term falling or rising tendency in the DIA light curve, see Soszyński *et al.* 2002), variability of blending stars or probably by pulsations of one of the binary components. All variables with additional, confirmed or only suspected, light curve changes are marked with "Puls" or "Puls?" remark, respectively. We did not perform any search for other periods in the light curves of those stars, however we provide this information for two examples. The first object is the star, noted also in Graczyk (2003), with the ID number 661 in our catalog (SMC_SC6 OGLE005139.70-731844.8), where EA class star with period equal to 5.72593 days is probably blended with another EA star with period of 2.617744 days. Light curve of another star no. 778 (SMC_SC6 OGLE005253.03-731111.8), exhibits also two periodicities: 1.25171 days and 1.51228 days (EW and EA class respectively).

Additionally, we found 224 eclipsing variables with effects of orbit eccentricity visible in their light curves. They were marked with "ecc" remark. In 49 cases we could not smooth both eclipses using the same period what could be caused by large apsidal motion. We marked these objects as "eccAP" and selected the period that smooths the primary minimum.

4. Catalog of Eclipsing Binary Stars

In total 1351 eclipsing binary stars were found in the OGLE-II DIA catalog of variable stars in the SMC fields. List of the first 50 stars is presented in Table 2. It contains the ordinal number of the eclipsing variable star, field, name of the star, number in the previous version of the catalog, orbital period, heliocentric

T a b l e 2

Eclipsing binaries in the SMC

No.	Field	Star	OGLE No.	Period [days]	T_0 -2450000	V	$B-V$	$V-I$	$I_{\rm PRI}$ (DIA)	Type
1	SMC_SC1	OGLE003617.48-731331.9	–	249.189650	417.85070	16.74	−99.99	1.42	0.20	EB
2	SMC_SC1	OGLE003618.10-733315.2	–	1.602530	630.75054	17.07	−99.99	−0.15	0.28	EA
3	SMC_SC1	OGLE003621.53-732610.6	12977	60.387530	664.89765	14.64	0.21	0.27	0.54	EB
4	SMC_SC1	OGLE003639.62-730158.6	25589	3.396080	625.77915	17.29	0.01	0.01	0.27	EA-ecc
5	SMC_SC1	OGLE003654.82-732625.7	13290	0.411280	627.79314	20.65	−99.99	2.92	0.42	EA
6	SMC_SC1	OGLE003655.53-734219.4	6130	1.914720	625.93876	17.64	−0.11	−0.08	0.25	EA
7	SMC_SC1	OGLE003713.22-733244.3	–	1.253270	628.54204	17.02	−0.14	−0.11	0.13	EB
8	SMC_SC1	OGLE003716.81-731602.1	–	15.712600	629.93546	16.73	−99.99	0.26	0.22	EB
9	SMC_SC1	OGLE003725.33-733016.1	–	145.403380	585.68413	18.53	0.84	1.04	0.16	EA-uncertain
10	SMC_SC1	OGLE003726.44-731547.3	–	3.116580	628.96906	18.57	−99.99	0.06	0.44	EA-eccAP
11	SMC_SC1	OGLE003732.40-735619.2	27259	2.656750	626.97921	17.80	−0.08	0.02	0.64	EB
12	SMC_SC1	OGLE003736.43-733820.3	35641	29.056120	645.32761	18.50	0.37	0.80	0.23	EB/ELL
13	SMC_SC1	OGLE003738.86-734631.1	32309	3.819180	624.82105	16.35	−0.06	−0.08	0.47	EB
14	SMC_SC1	OGLE003744.93-734921.6	30716	2.449180	626.51258	17.36	−0.08	−0.03	0.78	EB
15	SMC_SC1	OGLE003753.54-732617.0	71827	1.646720	621.34310	18.45	−0.09	−0.00	0.67	EA
16	SMC_SC1	OGLE003759.97-732502.4	73863	6.215700	616.99756	19.62	0.61	0.95	0.72	EA
17	SMC_SC1	OGLE003804.71-735150.5	59297	3.796290	623.29900	19.41	0.04	0.28	1.31	EA
18	SMC_SC1	OGLE003805.03-731318.8	80268	1.521600	622.09109	17.79	−0.10	−0.03	0.46	EA
19	SMC_SC1	OGLE003814.59-730221.9	86988	70.299220	723.86261	18.31	−99.99	1.12	0.37	EA
20	SMC_SC1	OGLE003831.81-733308.7	69238	1.452910	620.89144	17.02	−0.16	−0.12	0.20	EA
21	SMC_SC1	OGLE003835.24-735413.2	58930	0.269090	621.77443	15.89	0.97	1.04	0.34	EW
22	SMC_SC1	OGLE003836.68-732607.6	73575	1.400540	620.97823	18.30	−0.10	0.00	0.46	EA
23	SMC_SC1	OGLE003838.15-730953.8	–	3.589650	619.51606	19.48	−99.99	0.36	1.62	EA
24	SMC_SC1	OGLE003843.72-732051.7	108663	1.474950	625.90916	18.94	−99.99	0.20	0.95	EB
25	SMC_SC1	OGLE003851.98-733433.2	99121	2.458900	619.06728	16.18	−0.16	−0.10	1.05	EB
26	SMC_SC1	OGLE003853.43-730323.8	–	0.554030	621.13419	18.49	0.07	0.05	0.72	EA
27	SMC_SC1	OGLE003858.13-732544.6	–	1.236260	621.05691	16.62	−0.05	0.21	0.12	EB/EW/ELL
28	SMC_SC1	OGLE003922.86-733905.2	–	102.126560	598.11308	17.33	1.38	1.32	0.14	EB/ELL
29	SMC_SC1	OGLE003924.70-732912.5	–	295.000000	790.84736	16.56	1.24	1.35	0.06	EB
30	SMC_SC1	OGLE003925.33-733835.9	97290	3.399940	618.48291	16.49	−0.13	−0.10	0.26	EA-ecc
31	SMC_SC2	OGLE003922.86-733905.2	–	102.126560	597.49608	17.35	1.40	1.32	0.15	EB/ELL
32	SMC_SC2	OGLE003925.33-733835.9	2742	3.399940	628.68054	16.49	−0.16	−0.11	0.29	EA-ecc
33	SMC_SC2	OGLE003927.37-733309.6	–	54.261380	646.26467	15.82	−99.99	0.09	0.21	EB/ELL+Puls
34	SMC_SC2	OGLE003933.91-731855.4	11454	1.523980	626.58340	17.28	−99.99	−0.12	0.74	EA
35	SMC_SC2	OGLE003937.81-732136.2	9700	0.886070	626.78352	17.82	−0.08	−0.06	0.24	EW
36	SMC_SC2	OGLE003941.37-725441.2	–	121.961620	646.94259	17.09	−99.99	1.40	0.08	EB/ELL
37	SMC_SC2	OGLE003942.78-734330.1	102	23.919760	644.67525	18.31	−99.99	0.96	0.27	EB
38	SMC_SC2	OGLE003946.11-733526.1	2788	1.977970	625.55118	16.38	−0.10	−0.10	0.92	EB
39	SMC_SC2	OGLE003952.15-730057.7	20205	1.006630	626.53331	18.77	−99.99	0.15	0.43	EW
40	SMC_SC2	OGLE004000.10-733814.0	2917	1.308830	628.95782	18.21	−0.08	−0.00	0.43	EA-ecc
41	SMC_SC2	OGLE004002.96-732703.4	7640	0.857110	626.07870	17.20	−0.12	−0.10	0.65	EW
42	SMC_SC2	OGLE004003.31-733722.5	–	2.823900	627.75032	16.00	−0.11	−0.13	0.12	EA/EB
43	SMC_SC2	OGLE004009.01-733857.3	27167	2.368930	626.10481	16.45	−0.11	−0.06	0.19	EB/EW/ELL
44	SMC_SC2	OGLE004010.63-730120.1	–	50.316720	583.38676	17.65	0.26	0.53	0.54	EA
45	SMC_SC2	OGLE004024.03-732227.0	35961	11.896940	619.67718	19.86	0.89	1.09	0.60	EA
46	SMC_SC2	OGLE004028.41-733757.4	28572	1.842440	620.84918	16.95	−0.14	−0.04	0.11	EB/ELL
47	SMC_SC2	OGLE004037.20-732757.7	–	1.232960	621.58291	19.13	0.03	0.18	1.57	EA
48	SMC_SC2	OGLE004039.89-733409.1	29990	5.911090	629.68464	16.94	0.04	−0.05	0.14	EA-ecc
49	SMC_SC2	OGLE004045.39-730205.1	–	47.399640	627.82925	18.59	−99.99	0.93	0.49	EA
50	SMC_SC2	OGLE004046.15-730833.0	–	1.968190	621.62198	19.03	−99.99	0.26	1.52	EB

Table 3

Cross-identification of eclipsing binary stars detected in overlapping regions

SMC_SC2 $\leftrightarrow$ SMC_SC1	OGLE003922.86-733905.2	SMC_SC2 $\leftrightarrow$ SMC_SC1	OGLE003925.33-733835.9
SMC_SC2 $\leftrightarrow$ SMC_SC3	OGLE004225.74-732930.7	SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004524.54-732236.1
SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004526.64-732531.1	SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004527.18-731549.8
SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004528.58-730301.8	SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004528.81-730611.2
SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004529.28-731006.9	SMC_SC3 $\leftrightarrow$ SMC_SC4	OGLE004530.36-730331.9
SMC_SC4 $\leftrightarrow$ SMC_SC3	OGLE004533.56-730528.3	SMC_SC4 $\leftrightarrow$ SMC_SC3	OGLE004534.08-731816.7
SMC_SC4 $\leftrightarrow$ SMC_SC5	OGLE004825.96-731745.8	SMC_SC4 $\leftrightarrow$ SMC_SC5	OGLE004827.65-732141.3
SMC_SC4 $\leftrightarrow$ SMC_SC5	OGLE004828.65-731348.8	SMC_SC4 $\leftrightarrow$ SMC_SC5	OGLE004828.90-731234.6
SMC_SC5 $\leftrightarrow$ SMC_SC4	OGLE004834.80-730652.6	SMC_SC5 $\leftrightarrow$ SMC_SC4	OGLE004836.63-733531.3
SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005125.57-731258.2	SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005126.84-731314.8
SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005127.02-731307.4	SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005128.13-731517.6
SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005129.62-732137.7	SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005130.22-725433.9
SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005131.91-724538.7	SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005134.05-724626.1
SMC_SC5 $\leftrightarrow$ SMC_SC6	OGLE005134.85-724545.9	SMC_SC6 $\leftrightarrow$ SMC_SC5	OGLE005135.04-731711.5
SMC_SC6 $\leftrightarrow$ SMC_SC5	OGLE005135.20-730420.8	SMC_SC6 $\leftrightarrow$ SMC_SC5	OGLE005135.64-725432.0
SMC_SC6 $\leftrightarrow$ SMC_SC5	OGLE005135.81-731244.8	SMC_SC6 $\leftrightarrow$ SMC_SC5	OGLE005136.23-732231.6
SMC_SC6 $\leftrightarrow$ SMC_SC6	OGLE005137.15-730550.2	SMC_SC6 $\leftrightarrow$ SMC_SC7	OGLE005429.00-731846.2
SMC_SC6 $\leftrightarrow$ SMC_SC7	OGLE005431.85-723510.9	SMC_SC6 $\leftrightarrow$ SMC_SC7	OGLE005432.05-725638.7
SMC_SC7 $\leftrightarrow$ SMC_SC6	OGLE005433.33-731315.0	SMC_SC6 $\leftrightarrow$ SMC_SC7	OGLE005434.50-724051.9
SMC_SC7 $\leftrightarrow$ SMC_SC6	OGLE005434.68-725912.9	SMC_SC7 $\leftrightarrow$ SMC_SC6	OGLE005437.09-730624.5
SMC_SC7 $\leftrightarrow$ SMC_SC8	OGLE005725.16-724738.7	SMC_SC7 $\leftrightarrow$ SMC_SC8	OGLE005727.51-723514.7
SMC_SC8 $\leftrightarrow$ SMC_SC7	OGLE005734.96-725335.3	SMC_SC8 $\leftrightarrow$ SMC_SC9	OGLE010023.48-725549.2
SMC_SC8 $\leftrightarrow$ SMC_SC9	OGLE010026.38-721503.4	SMC_SC9 $\leftrightarrow$ SMC_SC8	OGLE010028.97-725918.5
SMC_SC9 $\leftrightarrow$ SMC_SC10	OGLE010318.41-723608.1	SMC_SC9 $\leftrightarrow$ SMC_SC10	OGLE010319.89-722747.5
SMC_SC9 $\leftrightarrow$ SMC_SC10	OGLE010320.01-725004.3	SMC_SC9 $\leftrightarrow$ SMC_SC10	OGLE010323.85-723010.9
SMC_SC10 $\leftrightarrow$ SMC_SC11	OGLE010616.65-724117.2		

Julian Date of the primary minimum ($T_0 - 2\,450\,000$, corrected for the position of the star in the driftscan image, as described in Żebruń *et al.* 2001b), V-band magnitude, $B-V$ and $V-I$ colors at maximum brightness from the standard OGLE-II data pipeline PSF photometry, amplitude in the I-band from DIA photometry (depth of primary minimum) and eclipsing type. Color value of -99.99 indicates no observations in the B or V bands.

One should remember that the conversion of the DIA flux differences to the magnitude scale is not always accurate. In particular, in the case of severely blended objects the depth of minima can be unreliable, as the constant flux cannot be accurately determined. Nevertheless, such blends contain a real eclipsing star.

Among 1351 stars, 51 were identified twice in the overlapping regions between the neighboring fields, therefore the total number of eclipsing binary stars with independent measurements is equal to 1402. List of all cross-identified objects is presented in Table 3.

Because the DIA photometry data were taken from Żebruń *et al.* (2001b), stars' names follow their convention which is based on the equatorial coordinates

of the star for the epoch J2000 in the format:

OGLE*hhmmss.ss-ddmmss.s*

For example, OGLE003617.48-731331.9 stands for a star with coordinates RA = $00^{\mathrm{h}}36^{\mathrm{m}}17\overset{\mathrm{s}}{.}48$ and DEC = $-73^\circ13'31\overset{''}{.}9$.

733 stars were classified as EA, 570 as EB and 150 as EW type. These figures do not sum up to 1402, because of many multiple classifications. Appendices A–C present examples of DIA *I*-band light curves of types EA, EB and EW, respectively. The ordinate is the phase with 0.0 value corresponding to the deeper eclipse. Abscissa is the *I*-band magnitude. Light curve is repeated twice for clarity.

Tables, light curves and finding charts of all 1402 eclipsing binary objects are available from the OGLE INTERNET archive and *via* the WWW Interface (Section 7).

Please note that periods of several stars might be two times longer than the real one, because in the cases of faint stars and for noisy light curves, the secondary eclipse could not be reliably detected.

5. Discussion

We present 1351 eclipsing binary stars located in the central regions of the SMC found in the OGLE-II data collected during four observing seasons. The number of stars is, however, smaller than found in the previous release of the catalog (Udalski *et al.* 1998) based on the first 1.5 year of OGLE-II observations. This is likely due to incompleteness of the DIA catalog of variable stars in the Magellanic Clouds (Żebruń *et al.* 2001b), from which data for the present search were taken.

Only 896 stars were cross-identified with the previous catalog. It means, that 455 stars presented here are newly discovered eclipsing binary stars. The main improvements compared to the previous catalog include much longer time-base of observations (4 years) and use of the DIA photometry instead of convensional PSF photometry. In the dense stellar fields the former technique is superior to the latter. Overall, present light curves have lower photometric scatter, better phase coverage and they yield much more accurate periods.

A sample of light curves of eclipsing binary stars from both catalogs is presented in Fig. 1. Stars from the catalog of Udalski *et al.* (1998) are in the left column while the stars from the current catalog are in the right column. For some objects a small systematic shift up to about 0.05 mag between light curves in the two catalogs can be seen. Most likely it is due to differences in the zero point of calibrations or, as mentioned above, inaccuracies in the conversion of the DIA flux differences to the magnitude scale.

Fig. 2 presents histogram of the DIA *I*-band brightness for all eclipsing binary stars found in the SMC (solid lines) and for those, which were cross-identified with the previous edition of the catalog (dotted line). The number of stars grows up to about $I \approx 18$ mag and then falls down to zero at $I \approx 20$ mag. Newly discovered eclipsing binary stars (difference of solid and dotted lines on

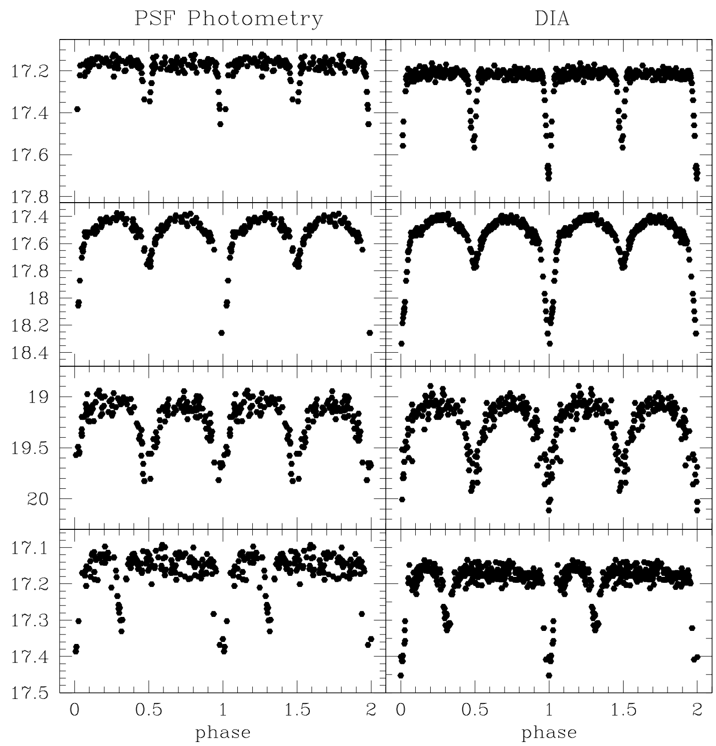

Fig. 1. Comparison of light curves of the eclipsing binary stars from the previous OGLE-II SMC catalog (Udalski *et al.* 1998) (left column) and present version (right column).

the histogram) are distributed more or less proportionally to the number of stars at a given brightness. Fig. 3 presents a picture of the SMC from the Digitized Sky Survey (DSS) with contours of the OGLE-II fields. Positions of the eclipsing binary stars are marked with dots. The stars are distributed proportionally to the density of the SMC stars, with the largest concentration in the fields SMC_SC4–SMC_SC6.

Fig. 4 shows the histogram of orbital periods of the SMC eclipsing stars in 0.25 day bins from 0 to 10 days. Dashed (red), dot-dashed (green) and solid (blue) lines correspond to classes EA, EB and EW, respectively, and dotted (black) line corresponds to all eclipsing objects. Additional 235 objects with periods longer than 10 days are distributed more or less uniformly and their number falls to zero at longer periods. The majority of stars are short period systems with the most frequent period of about 1 day. The longest period equals to 632.615 days (SMC_SC3 OGLE004402.68-725422.5), but both eclipses of this star are very similar and it is possible, that the real period is twice that long if the star has very faint secondary minima, invisible in our data. Another star (SMC_SC4 OGLE004617.60-731859.0) has the period equal to 580.5 days.

Fig. 5. presents I *vs.* $V-I$ color-magnitude diagram for all eclipsing binary stars from the catalog. EA, EB and EW classes are marked with different

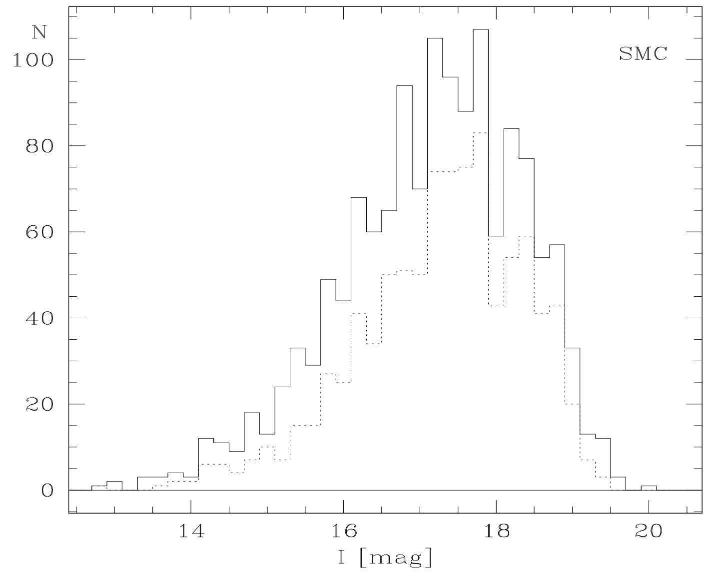

Fig. 2. Histogram of the DIA I-band brightness in 0.2 mag bins for all eclipsing binary stars (solid line) and only those, which were cross-identified with the previous edition of the catalog (dotted line).

fig3.jpg

Fig. 3. OGLE-II fields in the SMC. Dots indicate positions of eclipsing stars. North is up and East to the left in the DSS image.

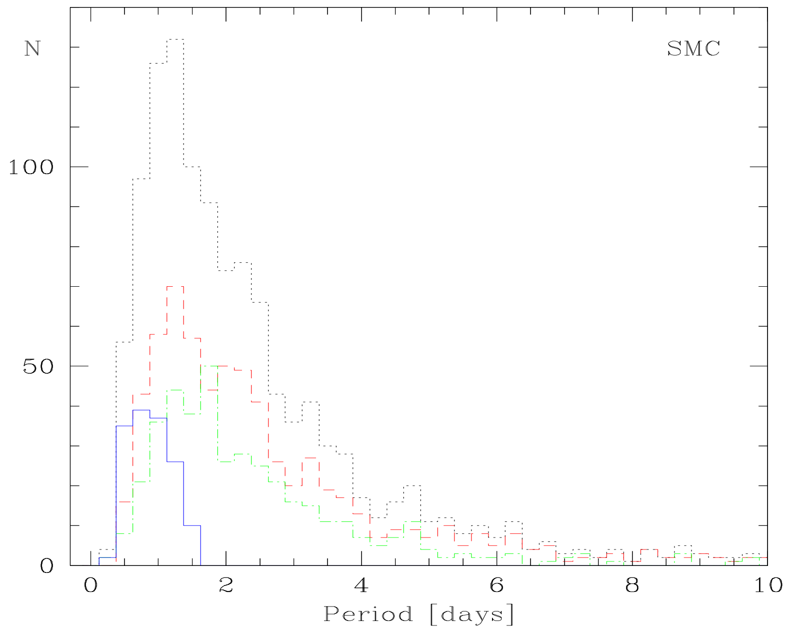

Fig. 4. Histogram of periods of eclipsing binaries in 0.25 day bins. Dashed (red), dot-dashed (green) and solid (blue) lines correspond to classes EA, EB and EW respectively. Doted (black) line corresponds to all eclipsing objects found in the SMC. Additional 235 objects have periods longer than 10 days.

symbols. Fig. 5 indicates, that most of the eclipsing stars belong to the SMC, but there are also some foreground stars, mostly EW class objects.

Another CMD diagram is presented in Fig. 6. Eclipsing binary stars are divided into 4 groups depending on their periods: short (less than 3 days), medium (from 3 to 7 days), long (from 7 to 15 days) and very long (more than 15 days). Each group is marked on the CMD with different symbol and color. The majority of short and medium period eclipsing stars are located on the main sequence and belong to the young population of stars. Part of the long period stars are located also on the main sequence, but some of them lie on the lower giant branch. Very long period eclipsing stars are mostly concentrated on the red giant branch.

6. Completeness of the Catalog

We compared our catalog of eclipsing binary stars in the SMC with the previous release by Udalski *et al.* 1998. They found 1527 objects (68 identified twice in overlapping fields) using the data covering first 1.5 year of observations of OGLE-II. Only 935 of them can be found in the DIA catalog of variable stars (Żebruń *et al.* 2001b), probably because of incompleteness of the DIA catalog

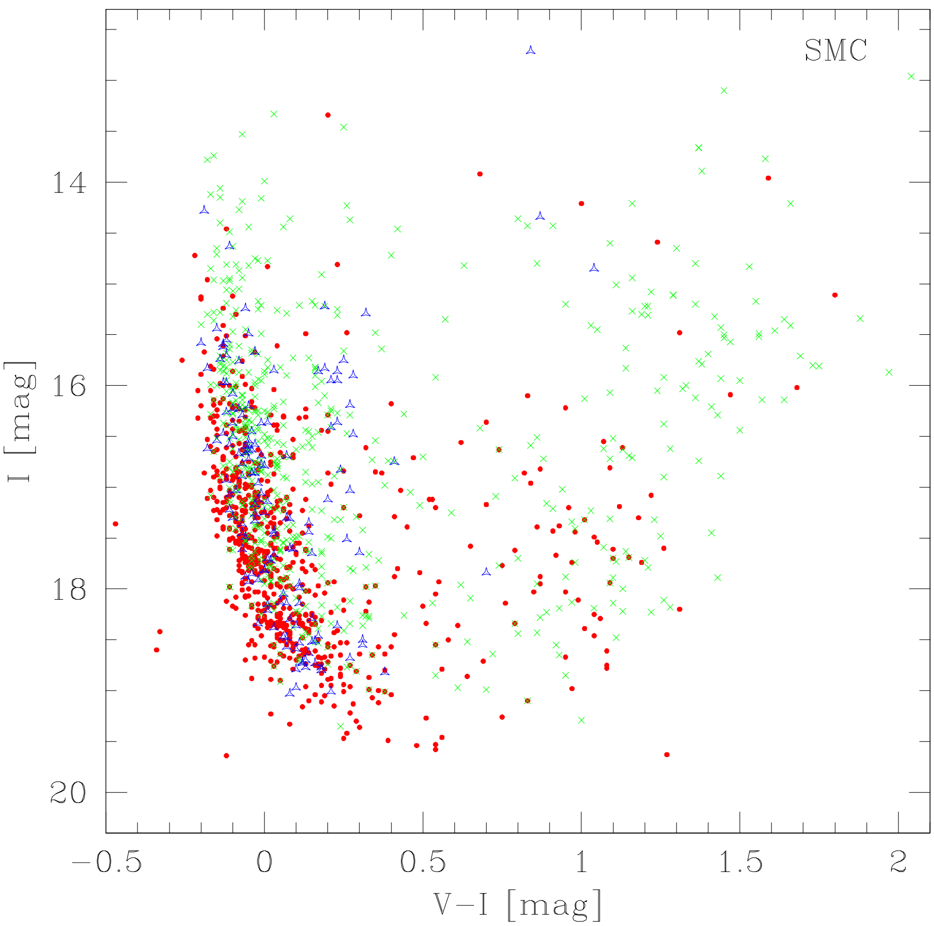

Fig. 5. Color-magnitude diagram of eclipsing binaries in the SMC. Red dots, green crosses and blue triangles mark EA, EB and EW type objects, respectively.

for faint stars. 30 out of 935 objects were not found in our preliminary results. In general, those were stars with periods very close to 1, 2 or 5 days and were excluded automatically before the network recognition process. Six objects had very bad photometry or turned out not to be an eclipsing object. Therefore, 24 stars total were added to our final catalog. This yields 97% efficiency of our search algorithm.

To estimate the completeness of our catalog we compared objects detected in the overlapping regions of neighboring fields. Based on astrometric solutions, we checked, which of the detected eclipsing binary stars should have a counterpart in the neighboring field and compared these objects with actually detected stars. In total, 102 stars should have a "twin" in the neighboring field. In practice 92 stars with pairs were found, yielding the mean completeness of our catalog

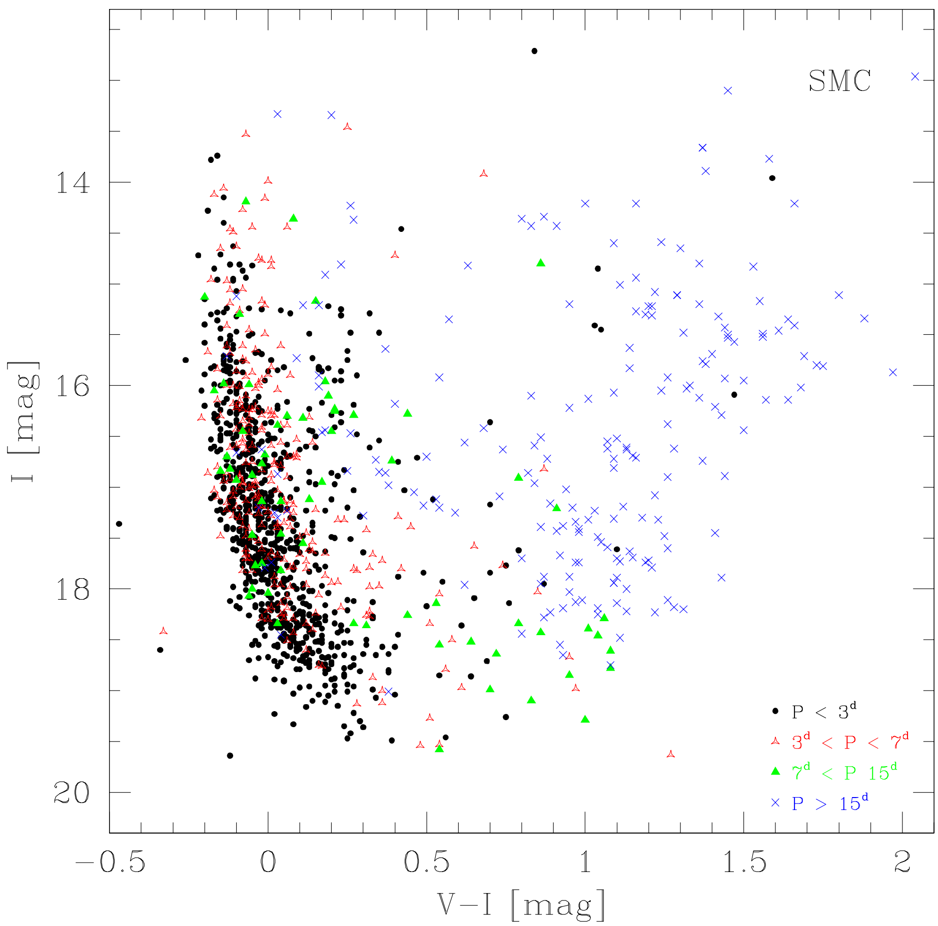

Fig. 6. Color-magnitude diagram of eclipsing binaries in the SMC. Different symbols mark position of stars with short, medium, long and very long periods.

equal to about 90%. This is certainly a lower limit value, because the edges of each field can be affected by non-perfect pointing of the telescope leading to effectively smaller number of observations and consequently to a smaller probability of variability detection.

Five missing pairs were subsequently added manually to the catalog. Parameters of all 102 paired stars were very similar to their "twins", however we unified them to the values of the star with larger number of data points.

7. The Catalog in the INTERNET

The catalog of eclipsing binary stars is available on-line through FTP and WWW from the OGLE INTERNET archive. The catalog can be accessed *via* anonymous FTP at the following addresses:

ftp://sirius.astrouw.edu.pl/ogle/ogle2/var_stars/smc/ecl
ftp://bulge.princeton.edu/ogle/ogle2/var_stars/smc/ecl

WWW interface to the catalog is available from the following addresses:

http://ogle.astrouw.edu.pl
http://bulge.princeton.edu/~ogle

The catalog will be regularly updated when the final set of the OGLE-II data becomes available and/or any errors (to some extent unavoidable in a dataset so large) are found. The most recent version will be available *via* INTERNET from the above addresses. The catalog will also be significantly extended when the number of epochs in the ongoing OGLE-III phase becomes large enough to facilitate good detection efficiency for eclipsing binaries. As the OGLE-III fields cover practically entire SMC our goal is to conduct a complete census of eclipsing stars in the SMC.

8. Summary

The new version of the catalog of eclipsing binary stars in the SMC based on the OGLE-II DIA catalog of variable stars in the Magellanic Clouds contains 1351 objects of three classical types: EA, EB and EW. 455 stars are newly discovered eclipsing binaries, not found in the previous edition of the catalog (Udalski *et al.* 1998). The exceptional good quality of the DIA photometry and very long time-base of the OGLE-II observations enabled construction of a uniform sample of eclipsing binaries with high quality light curves and very accurate periods. The catalog provides observational material for a variety of astrophysical studies in the SMC.

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Appendix A

Eclipsing stars in the SMC

EA type eclipsing stars

AppA.jpg

Appendix B

Eclipsing stars in the SMC

EB type eclipsing stars

AppB.jpg

Appendix C

Eclipsing stars in the SMC

EW type eclipsing stars

AppC.jpg